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(54) Abstract Title
Three-dimensional sound and graphics reproduction system

(57) A host processor unit (101) of a personal computer or game machine transfers scene data, drawing commands and sound commands to a geometric computation unit (102). The host processor unit or the geometric computation unit generates two-dimensional coordinate and colour data therefrom for a display, and the geometric computation unit identifies by computation the geometric relationship between a sound source and a point of listening. A sound generator (105) reads out, e.g. from a sound memory (104), sound data of a sound source specified by a sound command and reproduces sound in a three-dimensional space by processing the sound data, based on the geometric information from the geometric computation unit relating to the sound source and the point of listening. The sound data may relate to ambient sound, diffuse sound and directional sound.

FIG.1

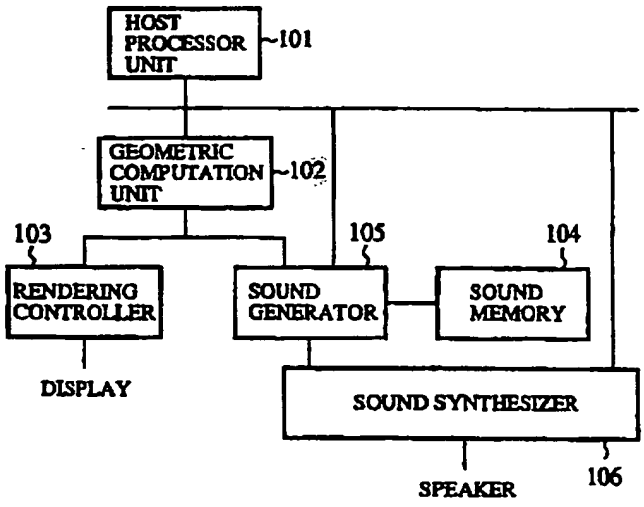

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FIG.3A

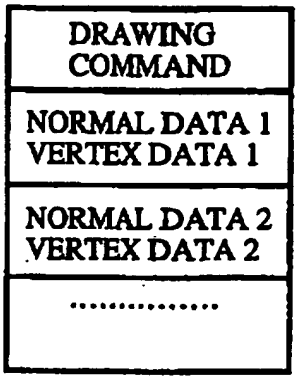


FIG.3B

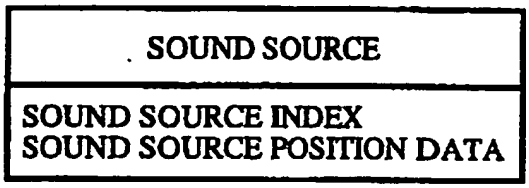


FIG.4

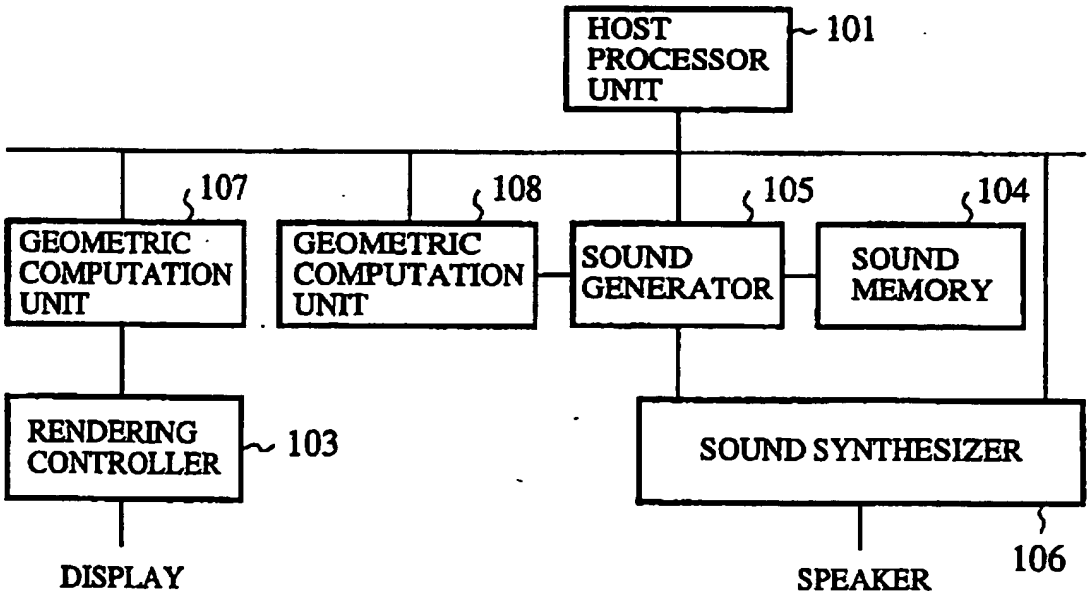


FIG.1

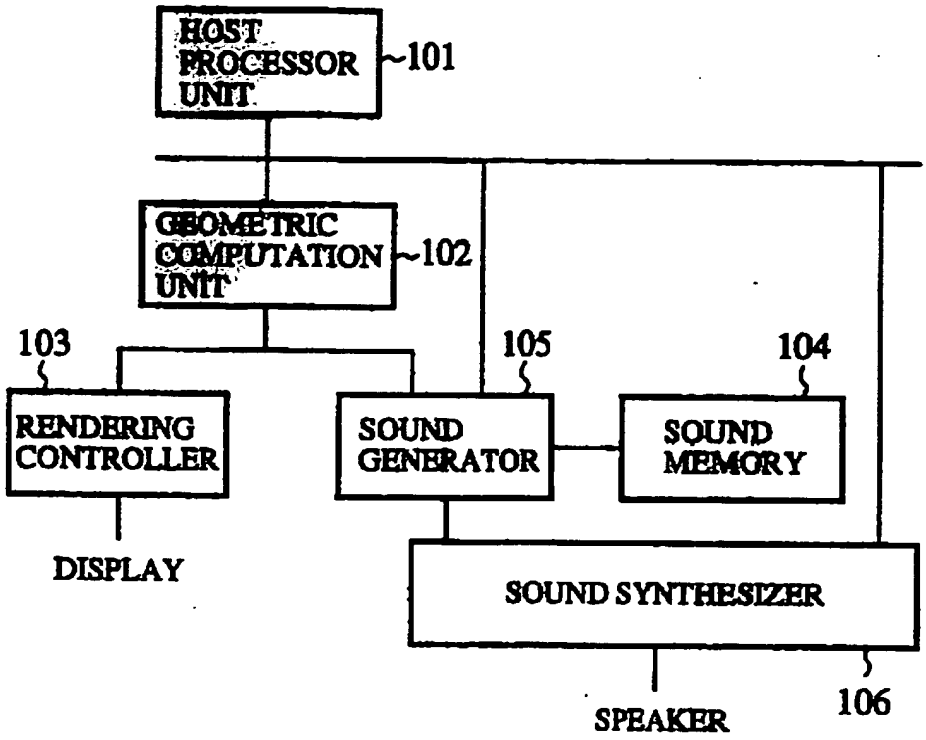

HOST PROCESSOR UNIT
101
GEOMETRIC COMPUTATION UNIT
102
103
105
104
RENDERING CONTROLLER
SOUND GENERATOR
SOUND MEMORY
DISPLAY
SOUND SYNTHESIZER
SPEAKER
106

FIG.2

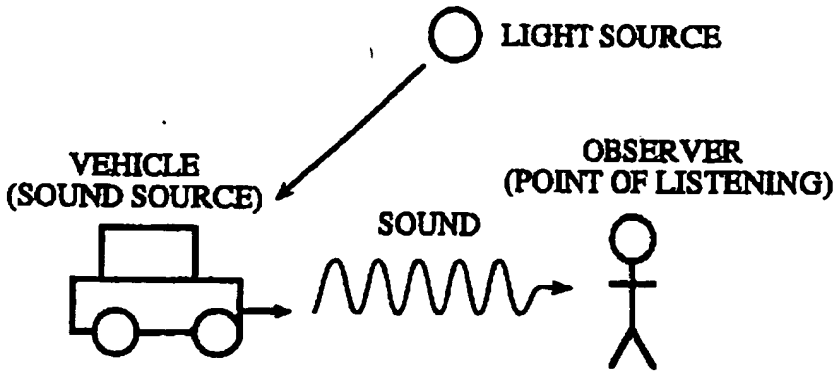

LIGHT SOURCE
VEHICLE (SOUND SOURCE)
OBSERVER (POINT OF LISTENING)
SOUND

FIG.5

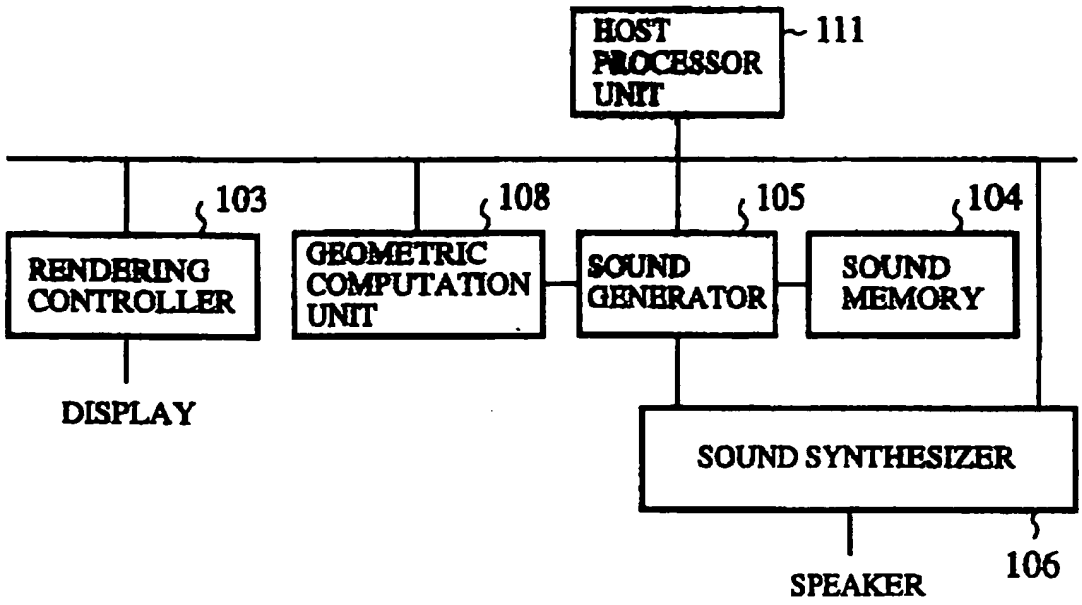

HOST PROCESSOR UNIT
111
103
108
105
104
RENDERING CONTROLLER
GEOMETRIC COMPUTATION UNIT
SOUND GENERATOR
SOUND MEMORY
DISPLAY
SOUND SYNTHESIZER
SPEAKER
106

FIG.6

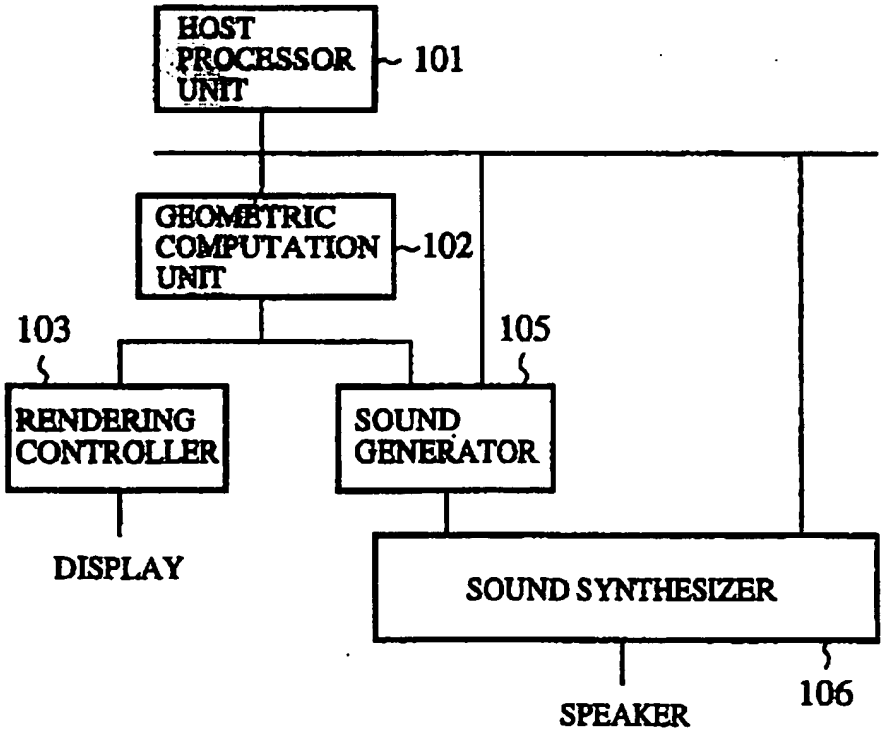

HOST PROCESSOR UNIT
101
GEOMETRIC COMPUTATION UNIT
102
103
105
RENDERING CONTROLLER
SOUND GENERATOR
DISPLAY
SOUND SYNTHESIZER
SPEAKER
106

FIG.7

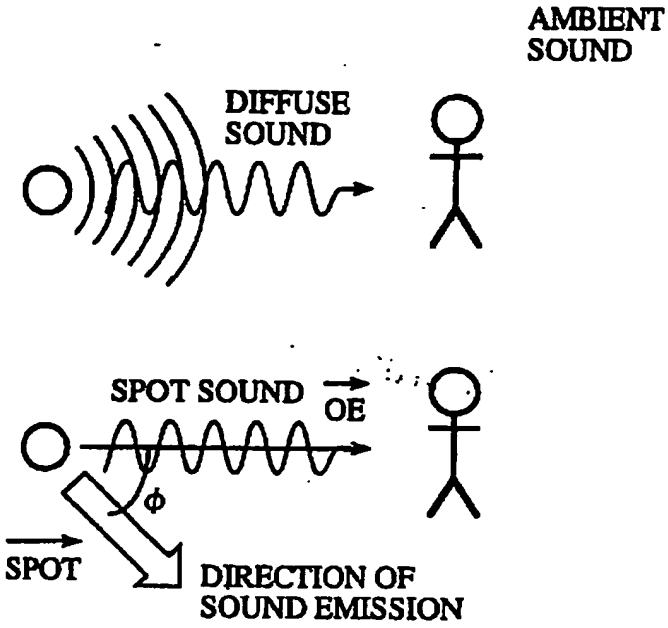

AMBIENT SOUND
DIFFUSE SOUND
SPOT SOUND
OE
ϕ
SPOT
DIRECTION OF SOUND EMISSION

FIG.8

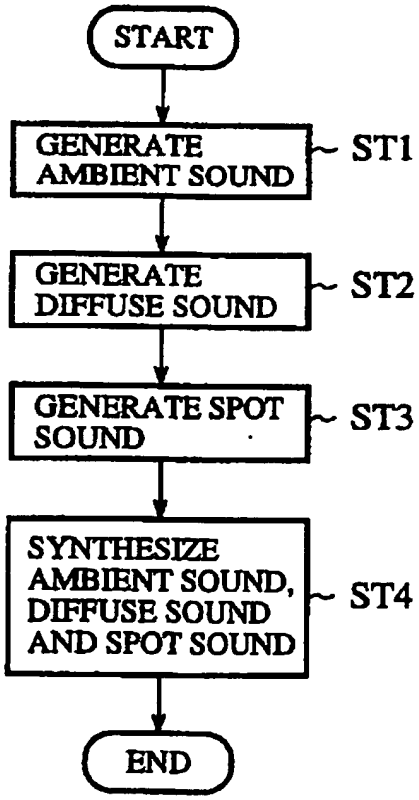
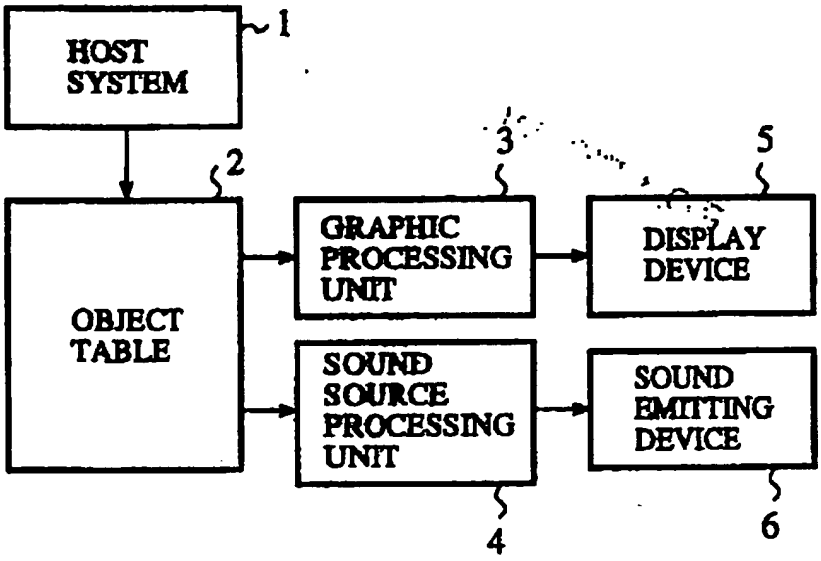

START
GENERATE AMBIENT SOUND
ST1
GENERATE DIFFUSE SOUND
ST2
GENERATE SPOT SOUND
ST3
SYNTHESIZE AMBIENT SOUND, DIFFUSE SOUND AND SPOT SOUND
ST4
END

FIG.9
(PRIOR ART)



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THREE-DIMENSIONAL SOUND REPRODUCTION SYSTEM

The present invention generally relates to a three-dimensional sound reproduction system and, more particularly, to a three-dimensional sound reproduction system for reproducing three-dimensional graphics and sound in a three-dimensional space.

In the accompanying drawings Fig. 9 shows a construction of a three-dimensional sound reproduction system according to the related art disclosed in Japanese Laid-Open Patent Application No. 8-149600. The system shown in Fig. 9 comprises a host system 1 comprising a personal computer, a game machine or the like, for executing a game program or a simulation; an object table 2 storing, for each of polygons constituting objects in three-dimensional computer graphics, three-dimensional coordinate values of vertices in the view coordinate system and displayed colors thereof. The object table 2 also stores sound information including tone, pitch and volume of a sound emitted from the vertices. The coordinate values of the vertices are modified on a real-time basis by the host system 1 in association with a change in a view point, movement of an object or

the like.

The data stored in the object table 2 is supplied to a graphic processing unit 3 and a sound source processing unit 4. The graphic processing unit 3 determines the coordinates of the vertices in the screen coordinate system, based on the coordinates, stored in the object table 2, of the vertices of the polygons in the view coordinate system. The graphic processing unit 3 also executes hidden-line elimination and hidden-surface elimination, executes a three-dimensional computer graphic processes such as shading and texture mapping, based on the displayed colors, thus creating three-dimensional images on the screen of a display device 5.

The sound source processing unit 4 determines a position of a virtual sound source and a position of a polygon relative to the sound source, based on the coordinate values of the vertexes of the polygon stored in the object table 2. The sound source processing unit 4 then generates sound via a sound emitting device 6, so that the sound is emitted from the position of the sound source thus identified toward the polygon, the sound being specified by associated sound information.

With the above-described construction of the related-art three-dimensional sound reproduction system, fine control of three-dimensional sound reproduction based on the

relationship between the sound source and a point of listening is difficult to achieve. A heavy load is imposed on a host system such as a CPU running an application such as a game, thus reducing its performance, because the CPU is responsible for real-time computation of information of the sound source and the point of listening, real-time converting of coordinate values in three-dimensional graphics and real-time computation of color information. Thus, high-quality three-dimensional graphics and three-dimensional sound reproduction is hard to implement.

Accordingly, an object of the present invention is to provide a three-dimensional sound reproduction system in which the aforementioned drawback is eliminated.

Another and more specific object is to provide a three-dimensional sound reproduction system implementing high-quality three-dimensional graphics and three-dimensional sound reproduction on a real-time basis.

The aforementioned objects can be achieved by a three-dimensional sound reproduction system for reproducing sound in a three-dimensional space in association with three-dimensional graphics, comprising: a host processor unit for storing graphic scene data and sound scene data constituting a three-dimensional scene, for

transferring drawing commands for drawing graphics and sound commands for reproducing sound and for controlling the entirety of the three-dimensional sound reproduction system; a geometric computation unit for performing geometric computation including conversion of coordinate values in three-dimensional graphics and computation of color information, based on the drawing command and the graphic scene data transferred from the host processor unit, so as to produce two-dimensional coordinate data and color data, and for identifying by computation geometric relationship between a sound source and a point of listening, based on the sound command and the sound scene data transferred from the host processor unit; a rendering controller for generating pixel data for display, based on the two-dimensional coordinate data and color data produced by the geometric computation unit; a sound memory for storing sound data of various sound sources; and a sound generator for reading out, from the sound memory, sound data corresponding to the sound command transferred from the host processor unit so as to generate sound in a three-dimensional space by processing the sound data thus read out, based on the geometric relationship between the sound source and the point of listening computed by the geometric computation unit.

The geometric computation system may include a first geometric computation unit for

performing geometric computation including conversion of coordinate values in three-dimensional graphics and computation of color information, based on the drawing command and the graphic scene data transferred from the host processor unit, so as to produce two-dimensional coordinate data and color data; and a second geometric computation unit for identifying by computation geometric relationship between the sound source and the point of listening, based on the drawing command and the graphic scene data transferred from the host processor unit.

The aforementioned objects can also be achieved by a three-dimensional sound reproduction system for reproducing sound in a three-dimensional space in association with three-dimensional graphics, comprising: a host processor unit for storing graphic scene data and sound scene data constituting a three-dimensional scene, for performing geometric computation including conversion of coordinate values in three-dimensional graphics and computation of color information, based on a drawing command for drawing graphics and graphic scene data, so as to produce two-dimensional coordinate data and color data, for transferring sound commands for reproducing sound, and for controlling the entirety of the three-dimensional sound reproduction system; a rendering controller for generating pixel data for display, based on the two-dimensional coordinate data and

color data produced by the hot processor unit; a geometric computation unit for identifying by computation geometric relationship between a sound source and a point of listening, based on the sound command and the sound scene data transferred from the host processor unit; a sound memory for storing sound data of various sound sources; and a sound generator for reading out, from the sound memory, sound data corresponding to the sound command transferred from the host processor unit so as to generate sound in a three-dimensional space by processing the sound data thus read out, based on the geometric relationship between the sound source and the point of listening computed by the geometric computation unit.

The sound memory may store ambient sound data for ambient sound in the three-dimensional space, diffuse sound data for non-directional diffuse sound transmitted directly from the sound source, and spot sound data for directional spot sound transmitted directly from the sound source; and the sound generator may generate the ambient sound in the three-dimensional space by reading out, from the sound memory, the ambient sound data for the ambient sound specified by the sound command transmitted from the host processor unit; generate the diffuse sound in the three-dimensional space by reading out, from the sound memory, the diffuse sound data for the diffuse sound specified by the sound command from the host processor unit and by

processing the diffuse sound data thus read out, based on the geometric relationship between the sound source and the point of listening computed by the geometric computation unit; generate the spot sound in the three-dimensional space by reading out, from the sound memory, the sound data for the spot sound specified by the sound command transferred from the host processor unit and by processing the sound data for the spot sound thus read out, based on the geometric relationship between the sound source and the point of listening computed by the geometric computation unit; and synthesize the ambient sound, the diffuse sound and the spot sound thus generated.

The aforementioned objects can also be achieved by a three-dimensional sound reproduction system for reproducing sound in a three-dimensional space in association with three-dimensional graphics, comprising: a host processor unit for storing graphic scene data and sound scene data constituting a three-dimensional scene, for transferring drawing commands for drawing graphics and sound commands for reproducing sound and for controlling the entirety of the three-dimensional sound reproduction system, the sound scene data including sound data for various sound sources; a geometric computation unit for performing geometric computation including conversion of coordinate values in three-dimensional graphics and computation of color information, based on the

drawing command and the graphic scene data transferred from the host processor unit, so as to produce two-dimensional coordinate data and color data, and for identifying by computation geometric relationship between a sound source and a point of listening, based on the sound command and the sound scene data transferred from the host processor unit; a rendering controller for generating pixel data for display, based on the two-dimensional coordinate data and color data produced by the geometric computation unit; a sound memory for storing sound data of various sound sources; and a sound generator for reading out, from the host processor unit, the sound data corresponding to the sound command transferred from the host processor unit so as to generate sound in a three-dimensional space by processing the sound data thus read out, based on the geometric relationship between the sound source and the point of listening computed by the geometric computation unit.

The host processor unit may store ambient sound data for ambient sound in the three-dimensional space, diffuse sound data for non-directional diffuse sound transmitted directly from the sound source, and spot sound data for directional spot sound transmitted directly from the sound source; and the sound generator may generate the ambient sound in the three-dimensional space by reading out, from the host processor unit, the ambient sound data for the ambient sound

specified by the sound command transmitted from the host processor unit; generate the diffuse sound in the three-dimensional space by reading out, from the host processor unit, the diffuse sound data for the diffuse sound specified by the sound command from the host processor unit and by processing the diffuse sound data thus read out, based on the geometric relationship between the sound source and the point of listening computed by the geometric computation unit; generate the spot sound in the three-dimensional space by reading out, from the host processor unit, the sound data for the spot sound specified by the sound command transferred from the host processor unit and by processing the sound data for the spot sound thus read out, based on the geometric relationship between the sound source and the point of listening computed by the geometric computation unit; and synthesize the ambient sound, the diffuse sound and the spot sound thus generated.

The host processor unit may store sound data such as that of background music not related to the three-dimensional space, and the three-dimensional sound reproduction system may further comprise a sound synthesizer for synthesizing the sound in the three-dimensional space generated by the sound generator with the sound data from the host processor unit not related to the three-dimensional space.

The present invention will be further described by way of non-limitative example with reference to the accompanying drawings, in which:

Fig. 1 shows the construction of a three-dimensional sound reproduction system according to a first embodiment of the present invention;

Fig. 2 illustrates a relationship between a moving vehicle and an observer according to the first embodiment;

Figs. 3A and 3B show commands transferred by a host processor unit according to the first embodiment;

Fig. 4 shows the construction of a three-dimensional sound reproduction system according to a second embodiment of the present invention;

Fig. 5 shows the construction of a three-dimensional sound reproduction system according to a third embodiment of the present invention;

Fig. 6 shows the construction of a three-dimensional sound reproduction system according to a fourth embodiment of the present invention;

Fig. 7 illustrates types of sound simulated according to the fifth embodiment of the

present invention;

Fig. 8 is a flowchart showing a process executed by a sound generator according to the fifth embodiment; and

Fig. 9 shows a construction of a three-dimensional sound reproduction system according to the related art.

First embodiment

Fig. 1 shows a construction of a three-dimensional sound reproduction system according to a first embodiment. Referring to Fig. 1, the three-dimensional sound reproduction system comprises a host processor unit 101 for storing graphic scene data and sound scene constructing a three-dimensional scene. The host processor unit 101, controlling the entire system, transfers drawing commands for drawing graphics and sound commands for reproducing sound. The host processor unit 101 also stores sound data not related to the three-dimensional space such as background music and beep sound (alert sound).

Referring also to Fig. 1, the three-dimensional sound reproduction system also comprise a geometric computation unit 102 for performing geometric computation including conversion of coordinate values in the three-dimensional graphics and computation of color information, based on the drawing command and the graphic scene data

transferred from the host processor unit 101, so as to produce two-dimensional object data comprising the coordinate data and color data. The geometric computation unit 102 also identifies by computation geometric relationship such as a distance between the sound source and the point of listening, and a magnitude of movement.

Referring also to Fig. 1, the three-dimensional sound reproduction system also comprise a rendering controller 103 for generating pixel data for display, based on the two-dimensional object data comprising the coordinate data and the color data computed by the geometric computation unit 102.

Referring also to Fig. 1, the three-dimensional sound reproduction system also comprises a sound memory 104 for storing sound data of various sound sources, a sound generator 105 for reading out, from the sound memory 104, sound data corresponding to a sound command transferred from the host processor unit so as to generate sound in a three-dimensional space by processing the sound data thus read out, based on the distance and the magnitude of movement computed by the geometric computation unit 102. The three-dimensional sound reproduction system also comprises a sound synthesizer 106 for synthesizing the three-dimensional sound generated by the sound generator 105 and the sound not related to the three-dimensional space read out from the host processor

101.

A description will now be given of the operation according to the first embodiment.

The mode by which the sound is heard depending on the movement of an object, a point of viewing or a point of listening is controlled by mapping a sound source to a three-dimensional object in three-dimensional graphics. Fig. 2 illustrates a relationship between a moving vehicle and an observer according to the first embodiment. It is assumed that a vehicle (sound source) emitting a sound, an observer (point of listening) and light source are provided in the three-dimensional graphics, as shown in Fig. 2. Assuming that the observer is viewing the vehicle, matrix conversion of the three-dimensional graphics into a point of viewing coordinate system having the eyes of the observer at the origin is conducted. Computation of color information related to the vehicle is performed at the positions of the light source, the vehicle and the eyes, respectively.

The three-dimensional data is converted into two-dimensional data so that the two-dimensional image is filled with color. The three-dimensional graphic process is applied to the sound source and the observer. Matrix conversion into a point of viewing coordinate system having the observer at the origin is conducted so that the relative and dynamic geometric relationship between the sound source and the observer is identified.

The sound emitted from the vehicle is controlled three-dimensionally, based on the information thus collected.

The host processor 101 stores the graphic scene data such as vertex data, normal data and light source data of an object, such as a vehicle, constructing a three-dimensional scene. Fig. 3 Figs. 3A and 3B show commands transferred by the host processor 101 unit according to the first embodiment. Fig. 3A shows a drawing command for graphics and Fig. 3B shows a sound command.

In order to draw a scene and reproduce sound therefor, the host processor 101 transfers a plurality of drawing commands and sound commands, graphic scene data corresponding to the drawing command and sound scene data corresponding to the sound command, to the geometric computation unit 102. In transferring the commands, it is not necessary to differentiate between the drawing command and the sound command. The commands may be transferred in bulk using the direct memory access (DMA) transfer. Related-art software for allowing the host processor unit 101 of the three-dimensional graphic system to handle the data may be used to transfer the commands.

The geometric computation unit 102 converts three-dimension data into two-dimensional data by model view conversion defined in a graphic library such as OpenGL, clipping, color computation and device conversion, so as to produce object data

comprising two-dimensional coordinate data and color data. The rendering controller 103 fills he two-dimensional image with color, based on the object data comprising the coordinate data and the color data produced by the geometric computation unit 102, so as to generate pixel data displayed on the display device.

Responsive to the sound command, the geometric computation unit 102 identifies by computation the geometric relationship such as the distance between the sound source and the point of listening, and the magnitude of movement. Using the model view conversion as used in the three-dimensional graphics library, conversion into the point of viewing (point of listening) coordinate system having the eyes (ears) of the observer at the origin so that the relative position of the point of listening and the sound source is identified by computation. Information relating to the movement of the sound source or the point of listening should be determined in the world coordinate system before the conversion into the model view.

The sound generator 105 reads out, from the sound memory 104, the sound data corresponding to the sound source specified by the sound command and transferred from the host processor unit 101. The sound generator 105 processes the sound data thus read out, based on the geometric information relating to the sound source and the point of

listening and computed by the geometric computation unit 120, so as to generate sound in the three-dimensional space. Processes performed by the sound generator 105 include control of a sound level depending on the distance between the sound source and the point of listening, applying of the Doppler effect based on the information relating to the movement of the sound source and the point of listening, control of a sound level depending on the direction in which the sound is emitted.

The sound synthesizer 106 synthesizes the sound in the three-dimensional space generated by the sound generator 105 and the sound not related to the three-dimensional space such as background music and a beep read out from the host processor unit 101. The synthesized sound is output from the sound synthesizer 106.

According to the first embodiment, the sound not related to the three-dimensional space such as background music and a beep are stored by the host processor unit 101. The sound synthesizer 106 synthesizes the sound in the three-dimensional space generated by the sound generator 105 and the sound not related to the three-dimensional space read out from the host processor unit 101. The sound synthesizer 106 may not be provided in the three-dimensional sound reproduction system. By providing the sound synthesizer 106, the sound in the three-dimensional space may contain desired sound not related to the three-dimensional space.

As described above, according to the first embodiment, the sound source data for three-dimensional sound synthesis is processed as an object in the three-dimensional graphics. The host processor 101 transfers the drawing command, the sound command, the graphic scene data, the sound scene data to the geometric computation unit 102. The host processor unit 101 is relieved of a load of extra processes. The geometric computation unit 102 generates the three-dimensional graphics. The sound generator 105 generates the sound in the three-dimensional space, based on the result of computation by the geometric computation unit 102. With this, high-quality three-dimensional graphics and high-quality three-dimensional sound are reproduced on a real-time basis.

Second embodiment

Fig. 4 shows the construction of a three-dimensional sound reproduction system according to a second embodiment of the present invention. Referring to Fig. 4, the three-dimensional sound reproduction system comprises a geometric computation unit 107 for performing geometric computation including conversion of coordinate values in the three-dimensional graphics and computation of color information, based on the drawing command and the graphic scene data transferred from the host processor unit 101, so as to produce two-dimensional object data comprising

the coordinate data and color data. The three-dimensional sound reproduction system according to the second embodiment also comprises a geometric computation unit 108 for identifying by computation geometric relationship such as a distance between the sound source and the point of listening, and a magnitude of movement, based on the sound command and the sound scene data transferred from the host processor unit 101. The other aspects of the construction remains the same as the corresponding aspects according to the first embodiment shown in Fig. 1.

While the three-dimensional graphic process and the three-dimensional sound process are performed by the geometric computation unit 102 according to the first embodiment, the second embodiment is configured such that the three-dimensional graphic process and the three-dimensional sound process are separated.

A description will now be given of the operation according to the second embodiment.

The host processor unit 101 manages the drawing command and the sound command shown in Figs. 3A and 3B independently. The host processor unit 101 transfers the drawing command and the graphic scene data to the geometric computation unit 107 and transfers the sound command and the sound scene data to the geometric computation unit 108. The geometric computation unit 107 performs the three-dimensional graphic process and the geometric

computation unit 108 performs the three-dimensional sound process. The other processes according to the second embodiment are the same as the corresponding processes according to the first embodiment.

As has been described, according to the second embodiment, it is possible to process the sound source data for three-dimensional sound generation is processed as an object in the three-dimensional graphics. The host processor 101 transfers the drawing command and the graphic scene data to the geometric computation unit 107, transfers the sound command and the sound scene data to the geometric computation unit 108. The host processor unit 101 is relieved of a load of extra processes. The geometric computation unit 107 generates the three-dimensional graphics. The sound generator 105 generates the sound in the three-dimensional space, based on the result of computation by the geometric computation unit 108. With this, high-quality three-dimensional graphics and high-quality three-dimensional sound are reproduced on a real-time basis.

Third embodiment

Fig. 5 shows the construction of a three-dimensional sound reproduction system according to a third embodiment of the present invention. Referring to Fig. 5, the three-dimensional sound reproduction system comprises a host processor unit 111 for controlling the entire

system by storing graphic scene data and sound scene data constituting a three-dimensional scene, performing geometric computation including conversion of coordinate values in the three-dimensional graphics and computation of color information, based on the drawing command and the graphic scene data, so as to produce two-dimensional object data comprising the coordinate data and color data, and transferring the sound command. The host processor unit 111 also stores sound data not related to the three-dimensional space such as background music and beep sound (alert sound).

Referring to Fig. 5, the other aspects of the construction according to the second embodiment are the same as the corresponding aspects of the second embodiment shown in Fig. 4 except that the geometric computation unit 107 is eliminated. The host processor unit 111 shown in Fig. 5 includes the function of the geometric computation unit 107.

The geometric computation unit 102 of the first embodiment performs the three-dimensional graphic process and the three-dimensional sound process. According to the third embodiment, the three-dimensional graphic process and the three-dimensional sound process are separated from each other. The three-dimensional graphic process is performed by the host processor unit 111 and the three-dimensional sound process is performed by the

geometric computation unit 108.

A description will now be given of the operation according to the third embodiment.

The host processor unit 111 manages the drawing command and the sound command shown in Figs. 3A and 3B independently. The host processor unit 111 transfers the sound command and the sound scene data to the geometric computation unit 108 and performs geometric computation including conversion of coordinate values in the three-dimensional graphics and computation of color information, based on the drawing command and the graphic scene data, so as to produce two-dimensional object data comprising the coordinate data and color data.

The rendering controller 103 fills he two-dimensional image with color, based on the object data comprising the coordinate data and the color data produced by the host processor unit 111, so as to generate pixel data displayed on the display device. The other aspects of the process according to the third embodiment are the same as the corresponding aspects according to the second embodiment.

As described above, according to the third embodiment, the sound source data for three-dimensional sound synthesis is processed as an object in the three-dimensional graphics. The host processor unit 111 generates three-dimensional graphics, transfers the sound data and the sound scene data to the geometric computation unit 108.

The sound generator 105 generates the sound in the three-dimensional space, based on the result of computation by the geometric computation unit 108. With this, high-quality three-dimensional graphics and high-quality three-dimensional sound are reproduced on a real-time basis.

Fourth embodiment

Fig. 6 shows the construction of a three-dimensional sound reproduction system according to a fourth embodiment of the present invention. The construction according to the sixth embodiment differs from that of the first embodiment shown in Fig. 1 in that the sound memory 104 is eliminated. The first embodiment is configured such that the sound memory 104 stores sound data for various sound sources. In the fourth embodiment, however, the sound data for various sound sources is stored as part of scene data in the host processor unit 111. With this, an inexpensive three-dimensional sound system is constructed.

A description will now be given of the operation according to the fourth embodiment.

The sound generator 105 reads out sound data corresponding to a sound source specified by the sound command from the host processor unit 101 and processes the sound data, based on the geometric information relative to the sound source and the point of listening input from the geometric

computation unit 102. The other aspects of the fourth embodiment are the same as the corresponding aspects according to the first embodiment.

As described above, according to the fourth embodiment, the sound data for three-dimensional sound synthesis is processed as an object of the three-dimensional graphics. The host processor 101 transfers the drawing command, the sound command, the graphic scene data, the sound scene data to the geometric computation unit 102. The host processor unit 101 is relieved of a load of extra processes. The geometric computation unit 102 generates the three-dimensional graphics. The sound generator 105 generates the sound in the three-dimensional space, based on the result of computation by the geometric computation unit 102. The sound data for the sound sources is stored in the host processor unit 101. With this, high-quality three-dimensional graphics and high-quality three-dimensional sound are reproduced on a real-time basis using an inexpensive construction.

Fifth embodiment

The construction of the three-dimensional sound reproduction system according to the fifth embodiment is the same as the construction according to the first embodiment shown in Fig. 1. The fifth embodiment is configured such that the geometric computation unit for three-dimensional graphics is facilitated by simulating

sound as well as light, thereby reproducing realistic sound.

Fig. 7 illustrates types of sound simulated according to the fifth embodiment of the present invention. As shown in Fig. 7, a classification of sound into ambient sound and spot sound is given. The ambient sound does not have any explicit sound source but is ubiquitous throughout the entire three-dimensional space. Diffuse sound is non-directional sound direct from a sound source. Spot sound is emitted from a directional sound source. The total profile of sound is build by synthesizing these types of sound. The sound data for ambient sound, the sound data for diffuse sound and the sound data for spot sound are stored in the sound memory 104.

A description will now be given of the operation according to the fifth embodiment.

Fig. 8 is a flowchart showing a process executed by a sound generator according to the fifth embodiment. In step ST1, the sound generator 105 reads out sound data for ambient sound stored in the sound memory 104, based on the sound command transferred from the host processor unit 101. The sound generator 105 also generates, in the three-dimensional space, ambient sound (noise-like sound) analogous to ambient light of computer graphics.

In step ST2, the sound generator 105 reads out from the sound memory 104 the sound data for diffuse sound corresponding to the sound source

specified by the sound command transferred from the host processor unit 101. The sound generator 105 processes the sound data for diffuse sound thus read out, based on the geometric information relating to the sound source and the point of listening and computed by the geometric computation unit 102. Thereby, the sound generator 105 generates, in the three-dimensional space, the diffuse sound analogous to diffuse light of computer graphics. The diffuse sound is directly transmitted from the sound source in a non-directional manner.

In step ST3, the sound generator 105 reads out from the sound memory 104 the sound data for spot sound corresponding to the sound source specified by the sound command transferred from the host processor unit 101. The sound generator 105 processes the sound data for spot sound thus read out, based on the geometric information relating to the sound source and the point of listening and computed by the geometric computation unit 102. Thereby, the sound generator 105 generates, in the three-dimensional space, the spot sound analogous to spot light of computer graphics. The spot sound is directly transmitted from the sound source in a directional manner.

In step ST4, the ambient sound in the three-dimensional space generated in step ST1, the diffuse sound in the three-dimensional space generated in step ST2, the spot sound in the three-

dimensional space generated in step ST3 are synthesized so as to produce the entirety of the sound in the three-dimensional space. By processing the sound in the same manner as light is simulated, the sound in a three-dimensional space is easily simulated. The other aspects of the process are the same as the corresponding aspects according to the first embodiment.

The construction of the three-dimensional sound reproduction system according to the fifth embodiment could be the same as the construction according to the first embodiment shown in Fig. 1, the construction according to the second embodiment shown in Fig. 4 or the construction according to the third embodiment shown in Fig. 5. The construction according to the fifth embodiment could also be the same as the construction according to the fourth embodiment shown in Fig. 6, as long as the host processor 101 of Fig. 6 stores the sound data for ambient sound, the sound data for diffuse sound and the sound data for spot sound.

As described above, according to the fifth embodiment, the sound data for generating the three-dimensional sound is processed as an object in the three-dimensional graphics. The host processor unit 101 transfers the drawing command, the sound command, the graphic scene data and the sound scene data to the geometric computation unit 102. The host processor unit 101 is not required to

perform extra processes since the geometric computation unit 102 generates the three-dimensional graphics and the sound generator 105 simulates the sound in the three-dimensional sound according to the type of sound, based on the result of computation by the geometric computation unit 102. With this, real-time high-quality three-dimensional sound reproduction according to the type of sound and high-quality three-dimensional graphic reproduction is implemented.

The present invention is not limited to the above-described embodiments, and variations and modifications may be made without departing from the scope of the present invention.

CLAIMS

1. A three-dimensional sound reproduction system for reproducing sound in a three-dimensional space in association with three-dimensional graphics, comprising:

a host processor unit for storing graphic scene data and sound scene data constituting a three-dimensional scene, for transferring drawing commands for drawing graphics and sound commands for reproducing sound and for controlling the entirety of the three-dimensional sound reproduction system;

a geometric computation unit for performing geometric computation including conversion of coordinate values in three-dimensional graphics and computation of color information, based on the drawing command and the graphic scene data transferred from said host processor unit, so as to produce two-dimensional coordinate data and color data, and for identifying by computation geometric relationship between a sound source and a point of listening, based on the sound command and the sound scene data transferred from said host processor unit;

a rendering controller for generating pixel data for display, based on the two-dimensional coordinate data and color data produced by said geometric computation unit;

a sound memory for storing sound data of

various sound sources; and

a sound generator for reading out, from said sound memory, sound data corresponding to the sound command transferred from said host processor unit so as to generate sound in a three-dimensional space by processing the sound data thus read out, based on the geometric relationship between the sound source and the point of listening computed by said geometric computation unit.

2. The three-dimensional sound reproduction system according to claim 1, wherein said geometric computation system includes a first geometric computation unit for performing geometric computation including conversion of coordinate values in three-dimensional graphics and computation of color information, based on the drawing command and the graphic scene data transferred from said host processor unit, so as to produce two-dimensional coordinate data and color data; and a second geometric computation unit for identifying by computation geometric relationship between the sound source and the point of listening, based on the drawing command and the graphic scene data transferred from said host processor unit.

3. A three-dimensional sound reproduction system for reproducing sound in a three-dimensional space in association with three-dimensional graphics, comprising:

a host processor unit for storing graphic scene data and sound scene data constituting a three-dimensional scene, for performing geometric computation including conversion of coordinate values in three-dimensional graphics and computation of color information, based on a drawing command for drawing graphics and graphic scene data, so as to produce two-dimensional coordinate data and color data, for transferring sound commands for reproducing sound, and for controlling the entirety of the three-dimensional sound reproduction system;

a rendering controller for generating pixel data for display, based on the two-dimensional coordinate data and color data produced by said hot processor unit;

a geometric computation unit for identifying by computation geometric relationship between a sound source and a point of listening, based on the sound command and the sound scene data transferred from said host processor unit;

a sound memory for storing sound data of various sound sources; and

a sound generator for reading out, from said sound memory, sound data corresponding to the sound command transferred from said host processor unit so as to generate sound in a three-dimensional space by processing the sound data thus read out, based on the geometric relationship between the sound source and the point of listening computed by

said geometric computation unit.

4. The three-dimensional sound reproduction system according to claim 1, wherein said sound memory stores ambient sound data for ambient sound in the three-dimensional space, diffuse sound data for non-directional diffuse sound transmitted directly from the sound source, and spot sound data for directional spot sound transmitted directly from the sound source; and wherein

said sound generator generates the ambient sound in the three-dimensional space by reading out, from said sound memory, the ambient sound data for the ambient sound specified by the sound command transmitted from said host processor unit; generates the diffuse sound in the three-dimensional space by reading out, from said sound memory, the diffuse sound data for the diffuse sound specified by the sound command from said host processor unit and by processing the diffuse sound data thus read out, based on the geometric relationship between the sound source and the point of listening computed by said geometric computation unit; generates the spot sound in the three-dimensional space by reading out, from said sound memory, the sound data for the spot sound specified by the sound command transferred from said host processor unit and by processing the sound data for the spot sound thus read out, based on the

geometric relationship between the sound source and the point of listening computed by said geometric computation unit; and synthesizes the ambient sound, the diffuse sound and the spot sound thus generated.

5. The three-dimensional sound reproduction system according to claim 3, wherein said sound memory stores ambient sound data for ambient sound in the three-dimensional space, diffuse sound data for non-directional diffuse sound transmitted directly from the sound source, and spot sound data for directional spot sound transmitted directly from the sound source; and wherein

said sound generator generates the ambient sound in the three-dimensional space by reading out, from said sound memory, the ambient sound data for the ambient sound specified by the sound command transmitted from said host processor unit; generates the diffuse sound in the three-dimensional space by reading out, from said sound memory, the diffuse sound data for the diffuse sound specified by the sound command from said host processor unit and by processing the diffuse sound data thus read out, based on the geometric relationship between the sound source and the point of listening computed by said geometric computation unit; generates the spot sound in the three-dimensional space by reading out, from said sound memory, the sound data for the spot sound specified

by the sound command transferred from said host processor unit and by processing the sound data for the spot sound thus read out, based on the geometric relationship between the sound source and the point of listening computed by said geometric computation unit; and synthesizes the ambient sound, the diffuse sound and the spot sound thus generated.

6. A three-dimensional sound reproduction system for reproducing sound in a three-dimensional space in association with three-dimensional graphics, comprising:

a host processor unit for storing graphic scene data and sound scene data constituting a three-dimensional scene, for transferring drawing commands for drawing graphics and sound commands for reproducing sound and for controlling the entirety of the three-dimensional sound reproduction system, the sound scene data including sound data for various sound sources;

a geometric computation unit for performing geometric computation including conversion of coordinate values in three-dimensional graphics and computation of color information, based on the drawing command and the graphic scene data transferred from said host processor unit, so as to produce two-dimensional coordinate data and color data, and for identifying by computation geometric relationship between a sound source and a point of listening, based on the

sound command and the sound scene data transferred from said host processor unit;

a rendering controller for generating pixel data for display, based on the two-dimensional coordinate data and color data produced by said geometric computation unit;

a sound memory for storing sound data of various sound sources; and

a sound generator for reading out, from said host processor unit, the sound data corresponding to the sound command transferred from said host processor unit so as to generate sound in a three-dimensional space by processing the sound data thus read out, based on the geometric relationship between the sound source and the point of listening computed by said geometric computation unit.

7. The three-dimensional sound reproduction system according to claim 6, wherein said host processor unit stores ambient sound data for ambient sound in the three-dimensional space, diffuse sound data for non-directional diffuse sound transmitted directly from the sound source, and spot sound data for directional spot sound transmitted directly from the sound source; and wherein

said sound generator generates the ambient sound in the three-dimensional space by reading out, from said host processor unit, the

ambient sound data for the ambient sound specified by the sound command transmitted from said host processor unit; generates the diffuse sound in the three-dimensional space by reading out, from said host processor unit, the diffuse sound data for the diffuse sound specified by the sound command from said host processor unit and by processing the diffuse sound data thus read out, based on the geometric relationship between the sound source and the point of listening computed by said geometric computation unit; generates the spot sound in the three-dimensional space by reading out, from said host processor unit, the sound data for the spot sound specified by the sound command transferred from said host processor unit and by processing the sound data for the spot sound thus read out, based on the geometric relationship between the sound source and the point of listening computed by said geometric computation unit; and synthesizes the ambient sound, the diffuse sound and the spot sound thus generated.

8. The three-dimensional sound reproduction system according to claim 1, wherein said host processor unit stores sound data such as that of background music not related to the three-dimensional space, said three-dimensional sound reproduction system further comprising a sound synthesizer for synthesizing the sound in the three-dimensional space generated by said sound

generator with the sound data from said host processor unit not related to the three-dimensional space.

9. The three-dimensional sound reproduction system according to claim 3, wherein said host processor unit stores sound data such as that of background music not related to the three-dimensional space, said three-dimensional sound reproduction system further comprising a sound synthesizer for synthesizing the sound in the three-dimensional space generated by said sound generator with the sound data from said host processor unit not related to the three-dimensional space.

10. The three-dimensional sound reproduction system according to claim 6, wherein said host processor unit stores sound data such as that of background music not related to the three-dimensional space, said three-dimensional sound reproduction system further comprising a sound synthesizer for synthesizing the sound in the three-dimensional space generated by said sound generator with the sound data from said host processor unit not related to the three-dimensional space.

11. A three-dimensional sound reproduction system substantially as herein

described with reference to any of Figures 1 to 8 of the accompanying drawings.

Amendments to the claims have been filed as follows.

CLAIMS

1. A three-dimensional sound reproduction system for reproducing sound in a three-dimensional space in association with three-dimensional graphics, comprising:

a host processor unit for storing graphic scene data and sound scene data constituting a three-dimensional scene, for transferring drawing commands for drawing graphics and sound commands for reproducing sound and for controlling the entirety of the three-dimensional sound reproduction system;

a geometric computation unit for performing geometric computation including conversion of coordinate values in three-dimensional graphics and computation of color information, based on the drawing command and the graphic scene data transferred from said host processor unit, so as to produce two-dimensional coordinate data and color data, and for identifying by computation geometric relationship between a sound source and a point of listening, based on the sound command and the sound scene data transferred from said host processor unit;

a rendering controller for generating pixel data for display, based on the two-dimensional coordinate data and color data produced by said geometric computation unit;

a sound memory for storing sound data of

various sound sources; and

a sound generator for reading out, from said sound memory, sound data corresponding to the sound command transferred from said host processor unit so as to generate sound in a three-dimensional space by processing the sound data thus read out, based on the geometric relationship between the sound source and the point of listening computed by said geometric computation unit.

2. The three-dimensional sound reproduction system according to claim 1, wherein said geometric computation system includes a first geometric computation unit for performing geometric computation including conversion of coordinate values in three-dimensional graphics and computation of color information, based on the drawing command and the graphic scene data transferred from said host processor unit, so as to produce two-dimensional coordinate data and color data; and a second geometric computation unit for identifying by computation geometric relationship between the sound source and the point of listening, based on the drawing command and the graphic scene data transferred from said host processor unit.

3. A three-dimensional sound reproduction system for reproducing sound in a three-dimensional space in association with three-dimensional graphics, comprising:

geometric relationship between the sound source and the point of listening computed by said geometric computation unit; and synthesizes the ambient sound, the diffuse sound and the spot sound thus generated.

5. A three-dimensional sound reproduction system for reproducing sound in a three-dimensional space in association with three-dimensional graphics, comprising:

a host processor unit for storing graphic scene data and sound scene data constituting a three-dimensional scene, for transferring drawing commands for drawing graphics and sound commands for reproducing sound and for controlling the entirety of the three-dimensional sound reproduction system, the sound scene data including sound data for various sound sources;

a geometric computation unit for performing geometric computation including conversion of coordinate values in three-dimensional graphics and computation of color information, based on the drawing command and the graphic scene data transferred from said host processor unit, so as to produce two-dimensional coordinate data and color data, and for identifying by computation geometric relationship between a sound source and a point of listening, based on the

sound command and the sound scene data transferred from said host processor unit;

a rendering controller for generating pixel data for display, based on the two-dimensional coordinate data and color data produced by said geometric computation unit; and

a sound generator for reading out, from said host processor unit, the sound data corresponding to the sound command transferred from said host processor unit so as to generate sound in a three-dimensional space by processing the sound data thus read out, based on the geometric relationship between the sound source and the point of listening computed by said geometric computation unit.

6. The three-dimensional sound reproduction system according to claim 5, wherein said host processor unit stores ambient sound data for ambient sound in the three-dimensional space, diffuse sound data for non-directional diffuse sound transmitted directly from the sound source, and spot sound data for directional spot sound transmitted directly from the sound source; and wherein

said sound generator generates the ambient sound in the three-dimensional space by reading out, from said host processor unit, the

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Documents considered to be relevant:

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A	US 5768393 A	(Yamaha)	
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